Review of TIAX "Well-to-Wheels" Fuel Cycle Assessment

Prepared for:
Western States Petroleum Association (WSPA)

April 11, 2007

Environmental Resources Management

Delivering sustainable solutions in a more competitive world

ERM

Agenda

1. About ERM
2. Background - WSPA and the TIAX model
3. Explanation - WTW, WTT, and TTW
4. Objectives - ERM's review of TIAX model
5. Comparison - Other fuel cycle models reviewed
6. Findings
7. Conclusions

About ERM and Project Team Members

- ERM is the largest all-environmental consultancy in the world – most clients are from Industry
- Strong Life Cycle Assessment team
- Considerable experience with Petrochemical clients
- Project Team
  - John Beath – 25 + years operations, engineering, and environmental compliance for petrochemical clients
  - Simon Aumonier - Leads ERM Oxford-based LCA team; 20 yrs LCA experience
  - Michael Collins - 10 yrs LCA experience
  - Victoria Junquera – project manager, led TIAX review, recently constructed an LCA model for a US alternative energy manufacturing facility
  - Staff Reviewers: Peter Garrett, Guy Roberts, Amy Dudow, Colleen McCarthy

Background

- The TIAX Well-to-Wheels (WTW) model was commissioned by the California Energy Commission (CEC)
- Per AB-1007, CEC and California Air Resources Board (CARB) must develop a plan to increase use of alternative fuels
- TIAX WTW model is comprised of a Wells-to-Tank (WTT) portion and a Tank-to-Wheels (TTW) portion
- WSPA commissioned ERM to review the TIAX model

Objective of ERM's Review of TIAX Model

- Review TIAX model in detail
  - Review of assumptions and calculation methods
  - Determine whether the model has obvious errors or flaws
- Compare TIAX to other transportation fuel WTW studies
  - Determine whether the models use different assumptions/calculation methods
  - Determine whether there are differences/ inconsistencies
  - Compare results
- Determine whether TIAX model contains the analysis needed to support developing regulations

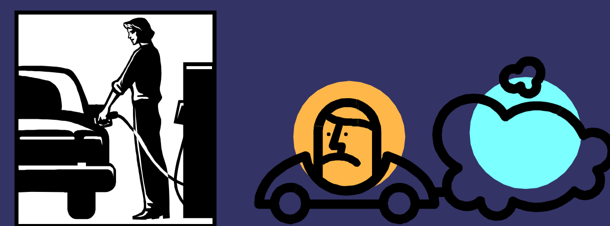
Scope

- ERM focused on the following fuel pathways:
  - BD20 from soybeans
  - Ethanol (corn)
  - Ethanol (cellulosic)
  - Gasoline
  - Diesel
- ERM focused on WTT portion of the TIAX WTW model

WTW, WTT, and TTW

- WTT: Feedstock extraction, transport to processing, processing/refining, and distribution (g/MJ-fuel)

- TTW: Vehicle refueling, evaporative and exhaust emissions (g/mile)



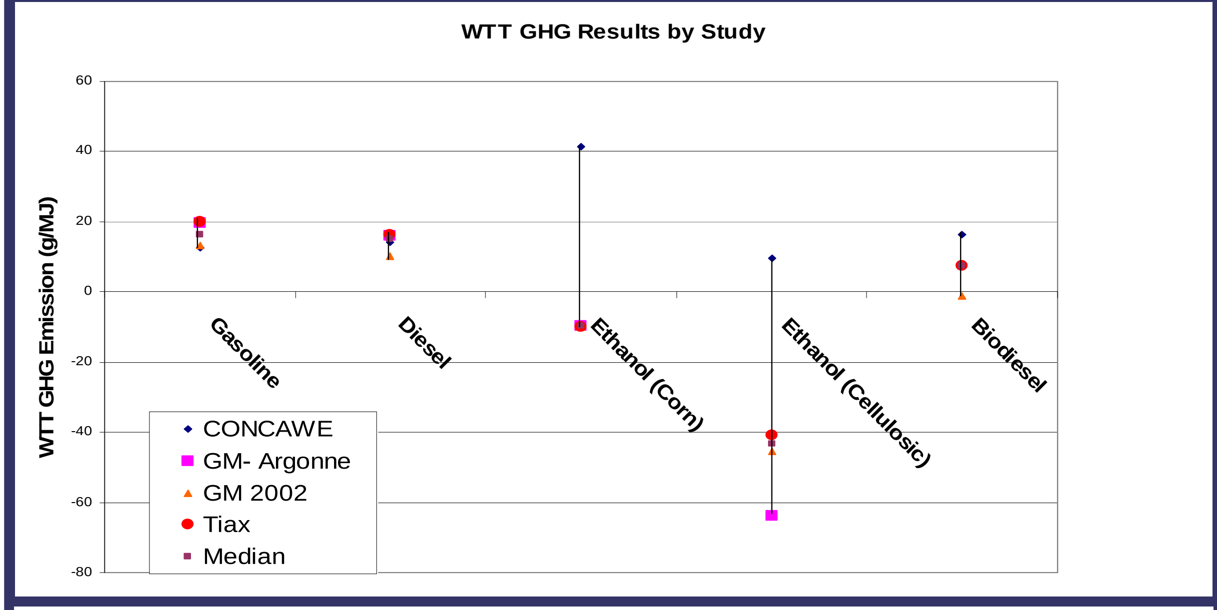
WTW (g/mile) = WTT (g/MJ-fuel) x vehicle fuel economy (MJ-fuel/mile) + TTW (g/mile)

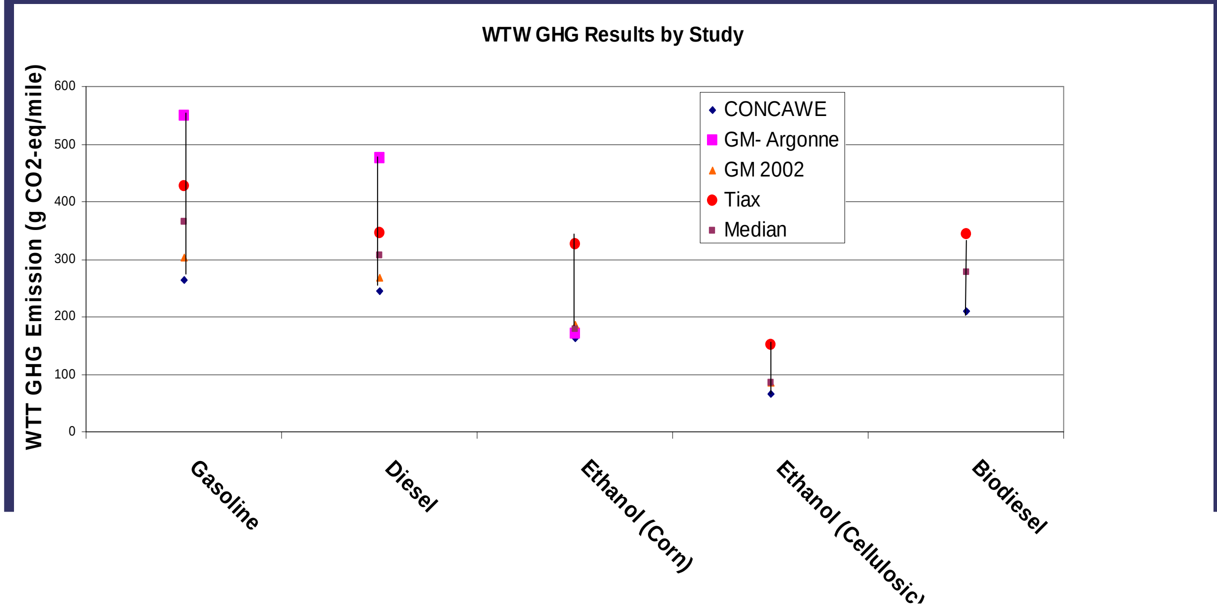
Study	Description
TIAX (February 2007)	• Report: Full Fuel Cycle Assessment Energy Inputs, Emissions, and Water Impacts: WTW, WTT, and TTW • Excel WTT Model: greet1.7row_us_ca_v53.xls • Excel WTW Model: wtw_processor 28 feb 07_r.xls
CONCAWE, EUCAR, and JRC, 2007 (European)	European Council for Automotive R&D (EUCAR), European Association for Environment, Health, and Safety in Refining (CONCAWE) and the European Union Commission's Join Research Centre (JRC) Well to Wheels Report (version 2c, March 2007)
GM-Argonne-BP-ExxonMobil-Shell, 2001 (North American)	GM-Argonne-BP-ExxonMobil-Shell study titled "Well to Wheel Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems, North American Analysis" (June,2001)
GM, 2002 (European)	GM "Well to Wheels Analysis of Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems – A European Study" (September 2002)
Delucci, 2003 (LEM)	Lifecycle Emissions Model (LEM) (Report December 2003), University of California Davis, Mark A. Delucchi. Addendum: Lifecycle Analyses of Biofuels (Draft manuscript, May 2006*)*

Overview of Other Models

Study	Description
CONCAWE, EUCAR, and JRC, 2007 (European)	Joint evaluation of the WTW energy use and GHG emissions for a wide range of potential future fuels and powertrains options
GM-Argonne-BP-ExxonMobil-Shell, 2001 (North American)	Uses GREET to estimate WTT energy and emission impacts of producing different transportation fuels. GM evaluated fuel economy and emissions of various vehicle technologies
GM, 2002 (European)	Prepared by GM, L-B-Systemtechnik, with support from BP, Sheel, ExxonMobil, and TotalFinalElf for CEC to identify alternative fuels and powertrains. Complements GM et al. (2001)
Delucci, 2003 (LEM)	Lifecyle Emissions Model (LEM) is a WTW model that estimates energy use, criteria pollutants, and GHG emissions for conventional and alternative energy sources for transportation fuels in the U.S.

Findings: Comparison With Other Models





WTT

- **Gasoline and Diesel:**
  - Small range between studies
  - TIAX in the upper range
- **Biofuels**
  - Large range between studies
  - TIAX in the mid to lower range

WTW

- **Gasoline and Diesel:**
  - Large range between studies
  - TIAX in the mid range
- **Biofuels**
  - Large range between studies
  - TIAX in the upper range

- Further study required to understand differences between studies

Findings: Comparison with Other Models (Cont'd)

Model Element	TIAX (2007)	CONCAWE (2007)	GM et al. (2001)	GM (2002)	Delucci (2003)
Infrastructure & Construction					X
Vehicle construction					
Fuel storage, distribution, and dispensing	X	X	X	X	X
Vehicle use	X	X	X	X	X
Land use change: crop changes	X	X			X
Forest land/grassland to agricultural land		X			X
Multi-sourcing of conventional fuels			X	X	X
Market size & sensitivity, economic considerations		X			X
Fertilizer manufacture	X	X	X	X	X
Gas leaks and flare usage	X				X
By-product benefit – substitution (displacement)		X	X	X	X
By-product benefit – allocation (mass, market price)	X		X		
Increase in refinery efficiency over time					X
Sensitivity and/or uncertainty analysis		X	X		X
N2O emissions not related to fertilizer use		X		X	X
Fertilizer effect on CH4 and CO2 emissions					X

Findings: Marginality Assumptions

- All marginal oil proceeds from the Middle East; refinery efficiency reflective of Middle East refineries
  - Impacts from refinery by-products are not included (e.g., residual oil can be used for electricity production, fuel, etc.)
- Corn feedstock and ethanol produced in Midwestern dry mills close to the farms on which the corn was grown
  - Distillers dry grain with solubles (DGS) by-product: 5.34 lbs/gal ethanol
  - Existing agricultural land used to grow corn
- Cellulosic feedstock and ethanol produced in California
- Soybeans and soybean oil produced in the Midwest; biodiesel produced in California
  - Existing agricultural land used to grow soybeans
  - Market exists for glycerin and soybean protein by-products
- >>> These assumptions have a large impact on the study results – their accuracy should be verified and a sensitivity analysis should be performed

Findings: Lack of Consideration of Market and Economic Drivers

- TIAX does not take into account market size and economic impacts of increased/decreased fuel consumption and by-product generation
  - Midwest's limited ability to provide all required corn and ethanol should demand increase beyond the model's assumption (5 billion gal/yr ethanol)
  - Saturated markets for biofuel by-products

Findings: Sensitivity / Uncertainty Analysis

- TIAX model does not incorporate uncertainty or sensitivity analysis
- ERM performed sensitivity runs:
  - +10% refining efficiency → WTT GHG emissions = -47% (CA RFG), -50% (ULSD)
  - -20% co-product yield → WTT GHG emissions = +497% (E85, corn) and + 16% (BD20, soybean)
  - +10% NO and N2O emissions from fertilizer use → WTT GHG emissions = +153% (E85, corn) and + 0.54% (BD20, soybean)
- **>>> Model assumptions can have a large impact on results; model sensitivity and uncertainty analyses are crucial**

Findings: Refinery Efficiency

- Refining Efficiency has large impact on WTT GHG emissions, moderate impact on WTW GHG emissions
  - Refining GHG emissions ~65% of WTT GHG emissions
  - WTT GHG emissions ~20% of WTW emissions
- Refining Efficiency not assumed to grow over time
- Lower efficiency than that estimated by MathPro (1999), EIA (2002), and Delucci (2003)
- In contrast, biocrop and biofuel production efficiency are assumed to increase

Findings: Land Use

- TIAX model does not take into account land use changes from grassland to agricultural land, or forest land to agricultural land
  - Land use changes are a very large source of WTT GHG emissions for biofuels: 26% for corn/ethanol and 63% for soy/biodiesel (Delucci, 2003)
- TIAX only takes into account switching between crops (agricultural land use changes)
  - These changes are based on a 5-billion gal/yr ethanol market and modest growth of energy crop cultivation in the U.S.
  - TIAX model does not consider GHG release resulting from reduced grain exports and hence increased overseas production

Findings: Multimedia Impacts

- Multi-media impacts include water consumed, wastewater (WW) produced, and pollutant discharge to water bodies
- Water impacts from refining operations are included in the model – lots of data available
- Agricultural runoff not included
  - Lack of available data
  - Agricultural activities assumed to occur outside California
- Water use for corn and soybeans assumed to be zero (non-irrigated cropland)
- Impacts from methanol leaks at biodiesel production facilities not taken into account

Findings: Conformance to Standards

- TIAX report does not conform to LCA ISO standards (ISO 14040) for
  - Documentation and Transparency
  - Data verification (precision, completeness, representativeness, source, and uncertainty)
  - Peer review: Peer reviews not included in the study
  - System Boundary: not clearly defined and explained
  - System flow diagram: not included
  - Discussion of allocation (e.g., energy usage across life cycle elements, etc.)
  - Uncertainty and sensitivity analysis

Conclusions

1. Large range of GHG among different WTW studies suggests that insufficient evidence exists to mandate a particular fuel policy
    a) Emissions should be calibrated against emission inventories to determine accuracy of TIAX model
    b) Large uncertainty suggests that insufficient evidence exists to mandate a particular fuel policy without further study

Conclusions (Cont'd)

2. Some assumptions in TIAX model might benefit the biofuel pathways

   a) Impacts associated with land use change from grassland or forest land to agricultural land were not included in the study and could lead to a large increase in CO_2 emissions from biofuels

   b) All marginal corn/ethanol and soyoil come from the Midwest All marginal corn/ethanol comes from the Midwest
      - All crude is extracted/refined in the Middle East

   c) Biofuel by-product benefit allocation with no regard to market size

   d) Agricultural runoff effects and water use for energy crops not included

   e) Biocrop cultivation & biofuel production efficiency increase over time (but refinery efficiency does not)

   f) Impacts from infrastructure and construction are not included; hence, impacts from the construction of biofuel plants, or from ethanol distribution infrastructure, are not included

Conclusions (Cont'd)

3. Lack of an uncertainty/sensitivity analysis undermines the usefulness of the TIAX model as a regulatory support tool

Contact Information

John M. Beath, P.E., (Texas)
Environmental Resources Management
2615 Calder, Suite 660
Beaumont, Texas 77702
409.833.7755
john.beath@erm.com